CASE STUDY:

Photonuclear Reactions on ^{242}Pu

- Introduction
  - Nuclear Reactions
  - Cross Sections
  - Photonuclear Reactions
- Why Photoreactions on ^{242}Pu?
- Preliminary Studies (Is an experiment worthwhile?)
- Exercises

Introduction

- Nuclear reaction
  - is a transformation of the nucleus of an atom by the incoming particle or photon. Incoming particle (or photon) is called projectile and the target is the original nucleus. Such reaction can lead to the formation of another, possibly chemically different isotope, called reaction product.
  - Target (projectile,emission) Product
  - X(a,b)Y
- Examples
  - (n,g), (n,p), (p,n), (n,α), (γ,n), ...
- First nuclear reaction observed by Rutherford in 1919
  - $^{14}N + {}^{4}He(alpha) \rightarrow {}^{17}O + {}^{1}H(proton)$
  - or $^{14}N(\alpha,p)^{17}O$

Introduction #2

- Cross-section
  - is used to describe the probability of interaction between a bombarding particle and the target nucleus. The cross section (denoted by Greek letter σ) depends on the properties of target nuclei, on the properties of projectile and on the energy of the projectile.
- Thin target

$$d\phi/dx = \sigma n \phi$$

σ [1b=10^{-24}cm^2] n [1/cm^3] ϕ [1/cm^2]

n – number of target nuclei per volume

ϕ – flux of projectiles

dx – thickness of the sample

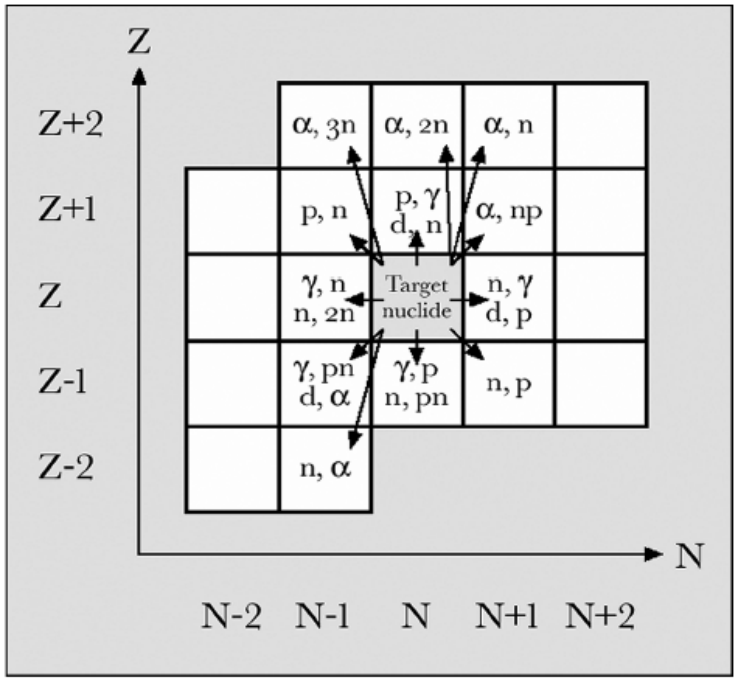
Number of Nuclear Reactions per Volume

Introduciton #3

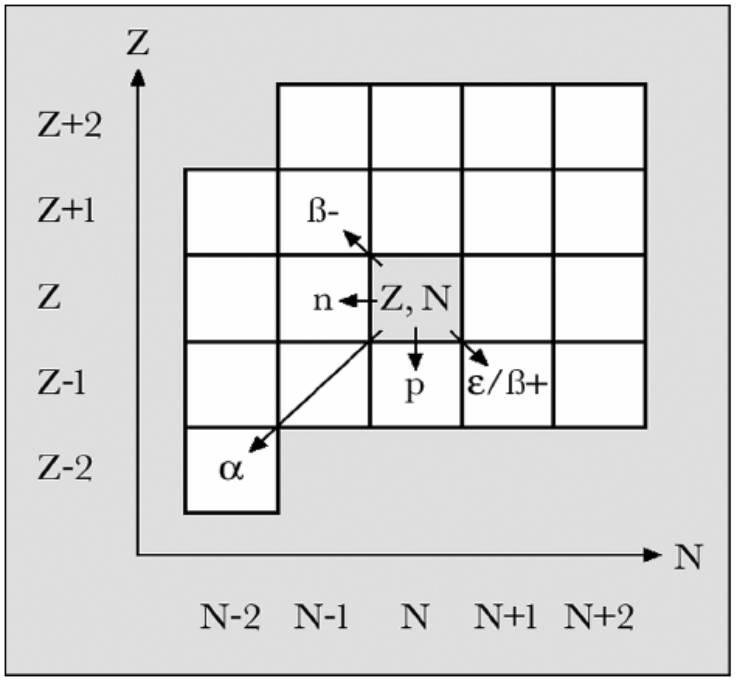
- Photonuclear reactions
  - can be observed for gamma photons with energies above several MeV. The excitation functions (σ) of all photonuclear reactions exhibit a large peak at photon energies from 25 MeV for light target nuclei to 14 MeV for heavy target nuclei.
  - This peak is named “giant dipole resonance” and is associated with collective oscillation of all the protons in the nucleus against the neutrons, which happens to be in resonance with the photon wave at this photon energy.
- There are many possible reactions at GDR
  - e.g. (γ,n), (γ,2n), (γ,np), (γ,α), (γ,n2p), (γ,2np), ..
  - In heavy nucleus (for Np and heavier) photo fission exhibits a sharp and important peak between 10 and 20 MeV.

Nuclear Reactions and Nuclides.net

- Reaction products on the nuclide chart.

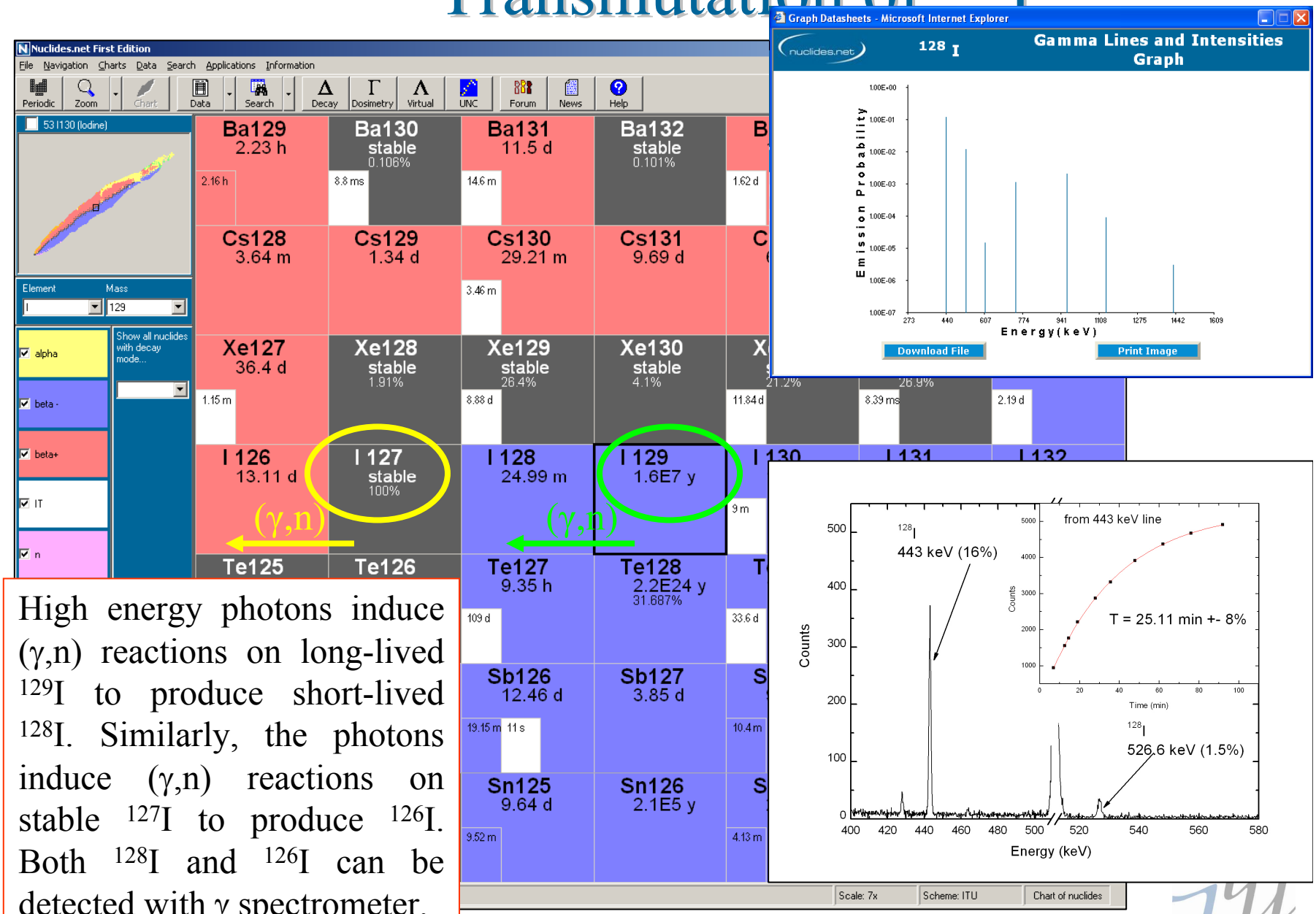


Relative locations of the nuclear reaction products.



Relative locations of the compound nucleus decay products.

Transmutation of ^{129}I



High energy photons induce (γ,n) reactions on long-lived ^{129}I to produce short-lived ^{128}I. Similarly, the photons induce (γ,n) reactions on stable ^{127}I to produce ^{126}I. Both ^{128}I and ^{126}I can be detected with γ spectrometer.

Transmutation of ^{129}I

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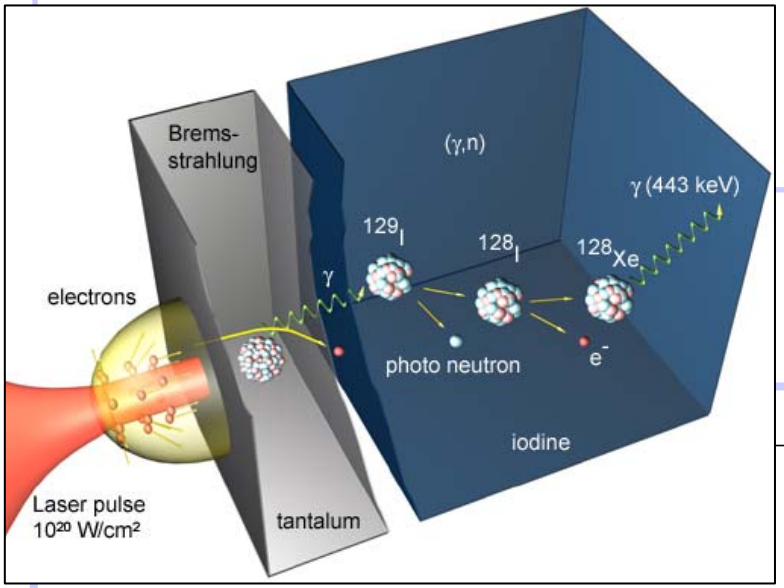
RAPID COMMUNICATION

Laser-driven photo-transmutation of ^{129}I—a long-lived nuclear waste product



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Laser transmutation of iodine-129

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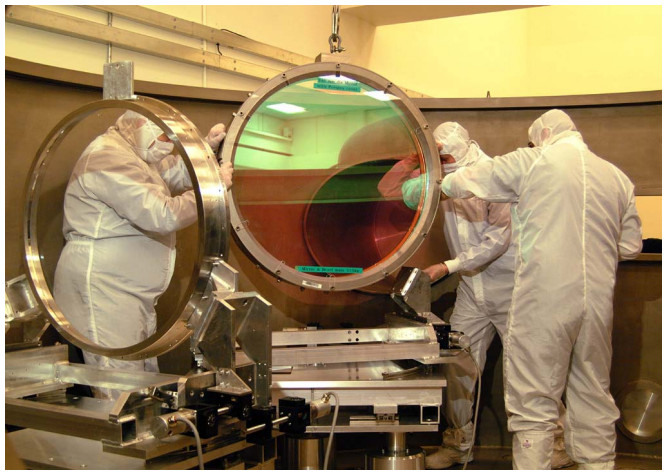
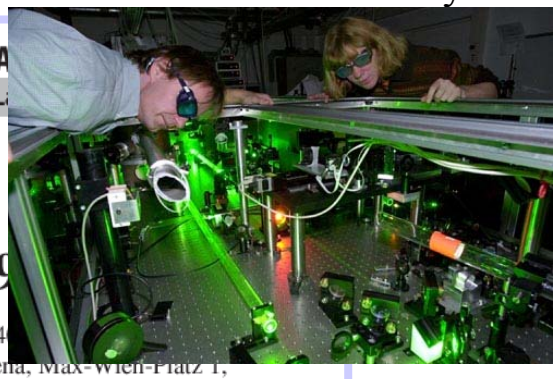
$$^{129}I\ \sigma_{(\gamma,n)} = 97 \pm 40mb$$



VULCAN giant pulse laser at RAL

High repetition rate tabletop laser at Jena University

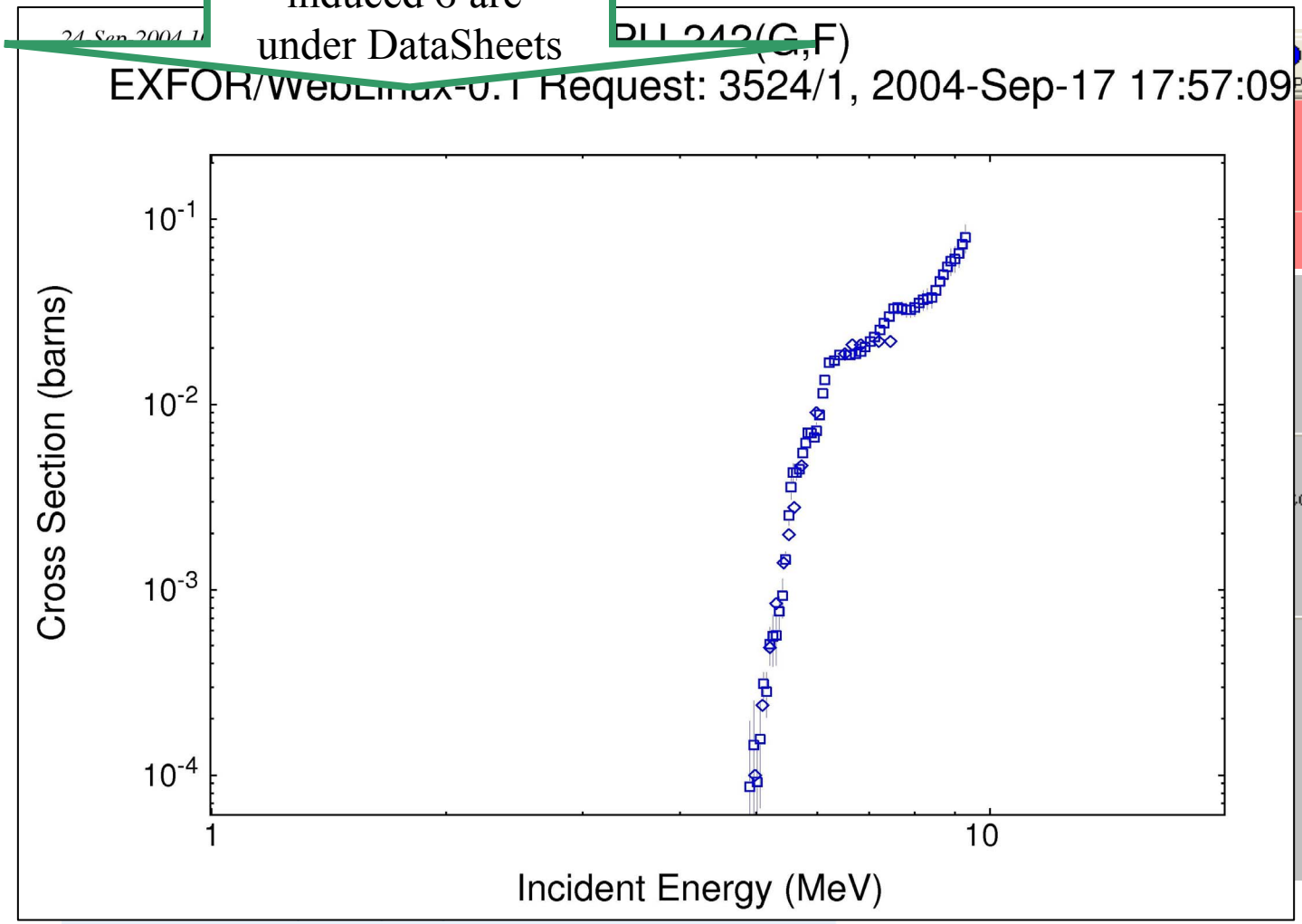


Photonuclear Reactions on Plutonium

- Interest in photonuclear cross section data
  - is powered by a number of different applications such as:
    - non-destructive detection of fissionable materials by gamma photons
    - cost effective intensive neutrons sources
    - transmutation of nuclear waste
    - medical applications
    - etc.
- As an example a preliminary study of an experiment involving photonuclear reactions on Pu will be presented
  - Literature survey and overview of the past experiments
    - How to find nuclear cross section data with Nuclides.net
  - ITU has a ^{242}Pu sample
    - Purity and in-growth?
  - We would like to use gamma spectroscopy to detect nuclear reactions
    - Which reaction products can we detect?
    - How can we avoid any unwanted gamma background?

How to serch for exparimental nuclear data?

Average neutron induced σ are under DataSheets



Decay Data Home Page (LBNL)

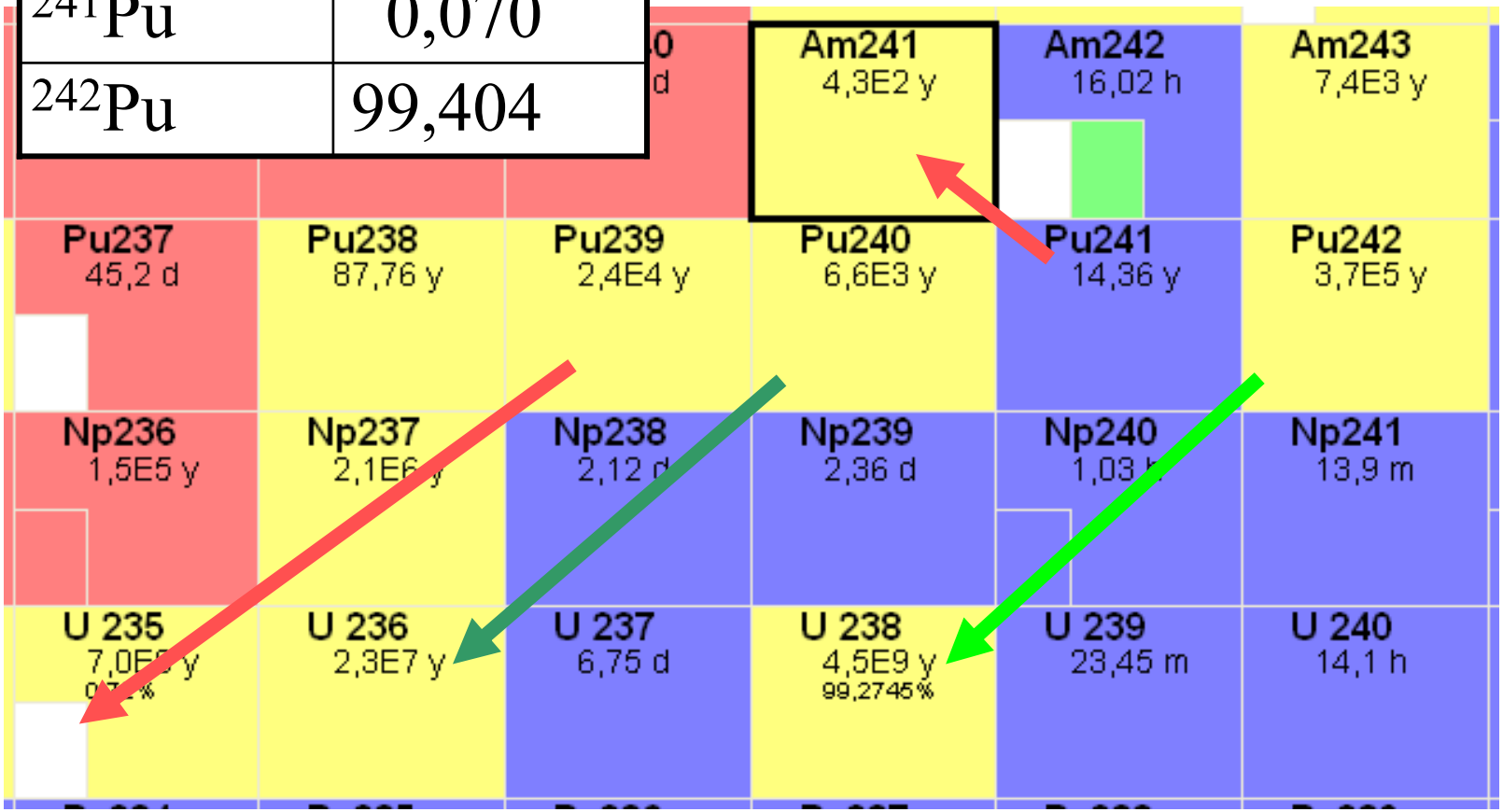
Others

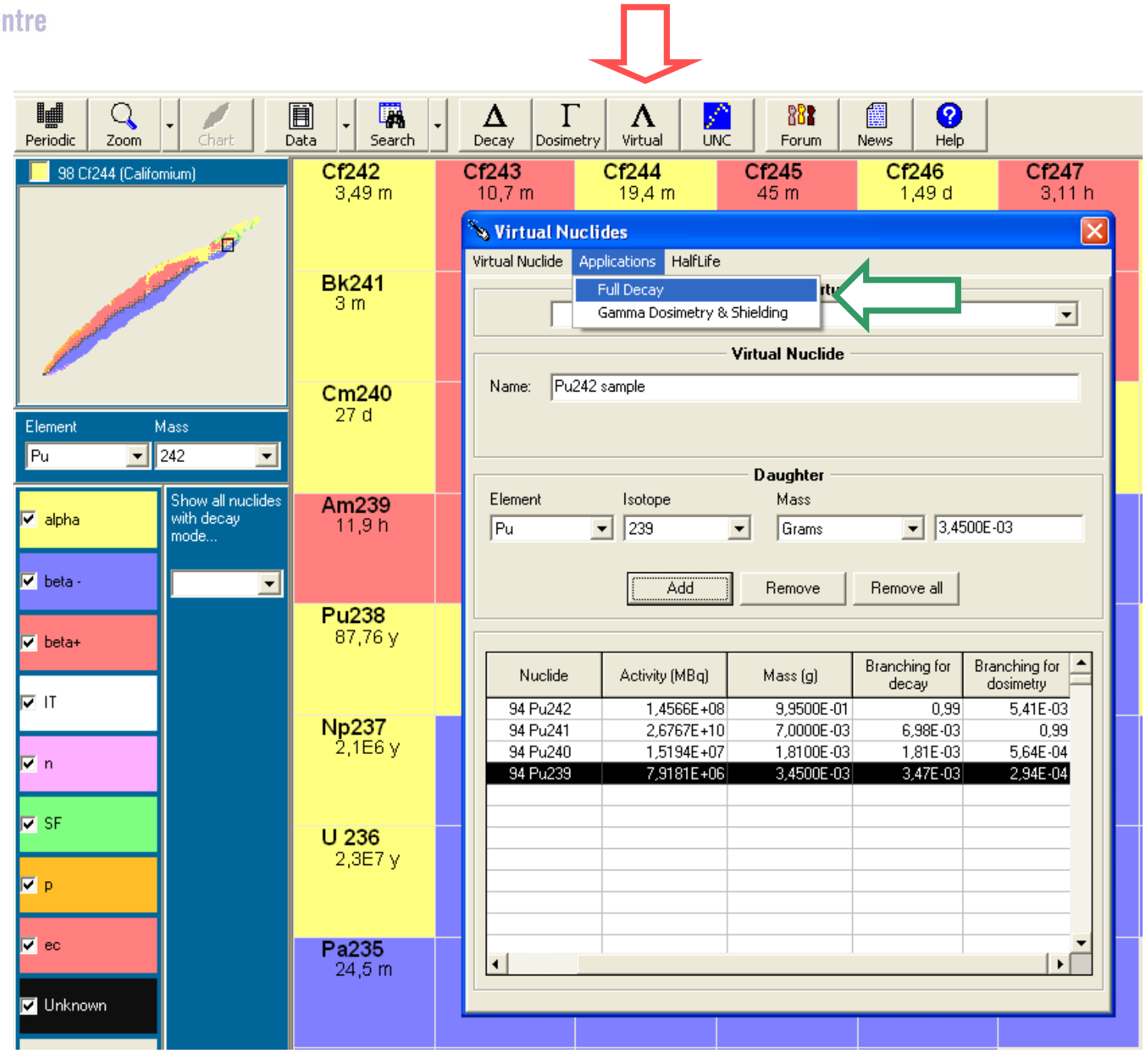
Organisations

Check t… …y?

Pu sample composition (average of 2 analyses, performed in Feb. 1992)

^{239}Pu	0,345
^{240}Pu	0,181
^{241}Pu	0,070
^{242}Pu	99,404




Periodic
Zoom
Chart
Data
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Decay
Dosimetry
Virtual
UNC
Forum
News
Help
98 Cf244 (Californium)
Element
Mass
Pu
242
alpha
beta -
beta+
IT
n
SF
p
ec
Unknown
Show all nuclides with decay mode...
Cf242 3,49 m
Cf243 10,7 m
Cf244 19,4 m
Cf245 45 m
Cf246 1,49 d
Cf247 3,11 h
Bk241 3 m
Cm240 27 d
Am239 11,9 h
Pu238 87,76 y
Np237 2,1E6 y
U 236 2,3E7 y
Pa235 24,5 m
Virtual Nuclides
Virtual Nuclide
Applications
HalfLife
Full Decay
Gamma Dosimetry & Shielding
Virtual Nuclide
Name:
Pu242 sample
Daughter
Element
Isotope
Mass
Pu
239
Grams
3,4500E-03
Add
Remove
Remove all
Nuclide
Activity (MBq)
Mass (g)
Branching for decay
Branching for dosimetry
94 Pu242 1,4566E+08 9,9500E-01 0,99 5,41E-03
94 Pu241 2,6767E+10 7,0000E-03 6,98E-03 0,99
94 Pu240 1,5194E+07 1,8100E-03 1,81E-03 5,64E-04
94 Pu239 7,9181E+06 3,4500E-03 3,47E-03 2,94E-04

Full Decay - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://139.191.191.201/Nuclides/Decay/N2K_FD_Engine.asp?fr=VB&mi=1163390&uk=02500803041048190001 Go Links

nuclides.net

Virtual Nuclide — Full Decay

Options

Quantity:	Grams	1.00726	**Distance(cm):**	100	**Min. Prod.:**	1E-04
Time:	Years	12	**Number of time steps:**	1	**N° Chains:**	9

Start

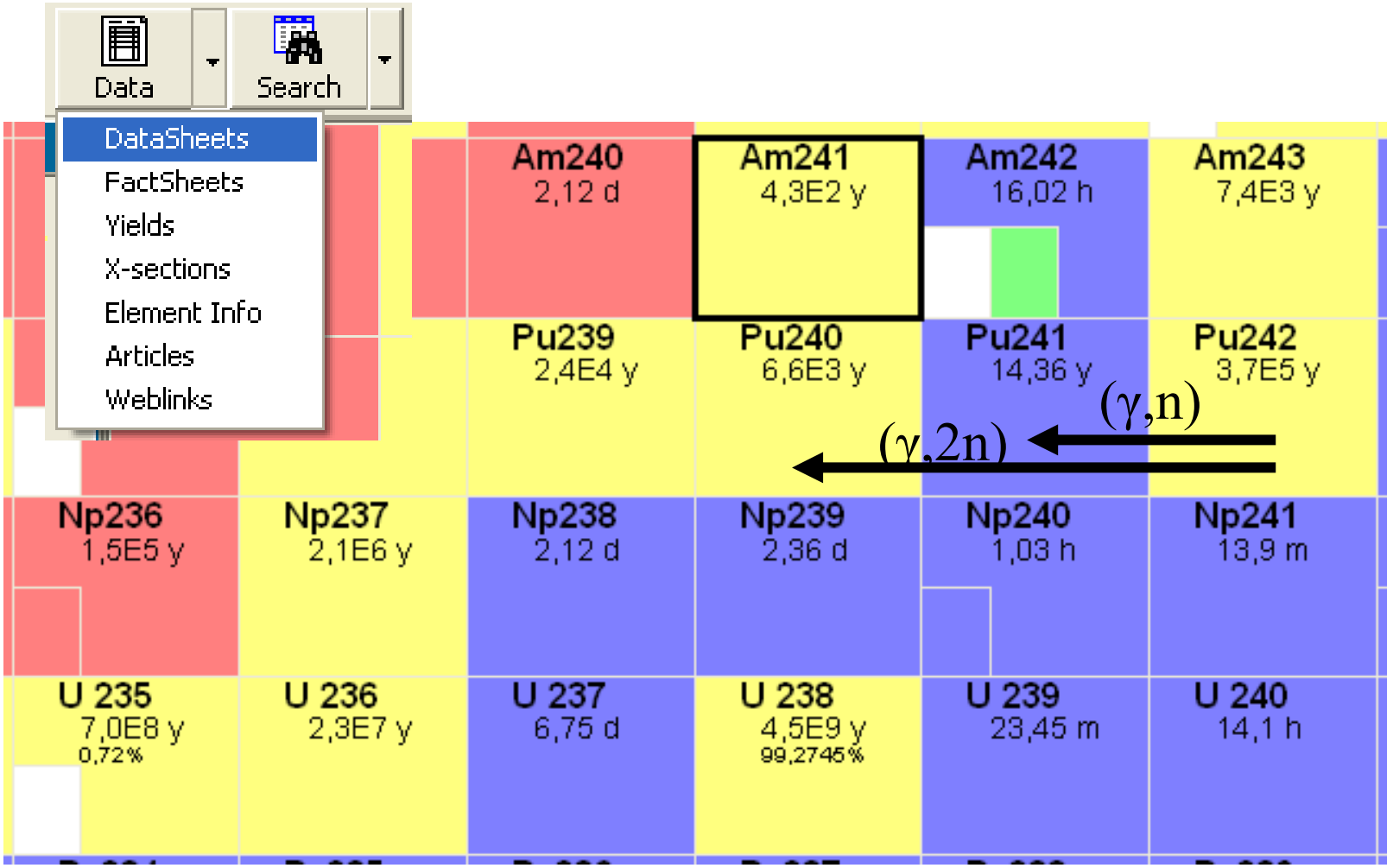
Reset

Parent+Daughters	N(atoms)	M(g)	A(Bq)
94 Pu242	2.4752E+21	9.9492E-01	1.4564E+08
92 U238	5.5115E+16	2.1787E-05	2.7095E-01
90 Th234	8.0747E+05	3.1381E-16	2.6879E-01
94 Pu241	9.7981E+18	3.9220E-03	1.4997E+10
95 Am241	7.6077E+18	3.0452E-03	3.8663E+08
93 Np237	8.0486E+16	3.1682E-05	2.2455E+02
86 Rn222	0.0000E+00	0.0000E+00	0.0000E+00
94 Pu240	4.5347E+18	1.8076E-03	1.5174E+07
92 U236	5.7459E+15	2.2522E-06	5.3888E+00
94 Pu239	8.6876E+18	3.4486E-03	7.9145E+06
92 U235 m	1.7127E+10	6.6848E-12	7.9145E+06
92 U235	2.9956E+15	1.1692E-06	9.3488E-02
82 Pb208 Stable	1.1681E+03	3.9951E-19	0.0000E+00
Total :	2.5060E+21	1.0072E+00	1.5561E+10

Print Graph Details

Wird geöffnethttp://139.191.191.201/Nuclides/Decay/RS_FD_Engine.asp?_method=RSEngine&_mtype=execute&pcount=9&p0=025008030410481 Internet

Photonuclear reactions on Plutonium



Exercise 1: Can we detect ^{240}Pu or ^{241}Pu with Ge detector?

Answer 1: Probably not

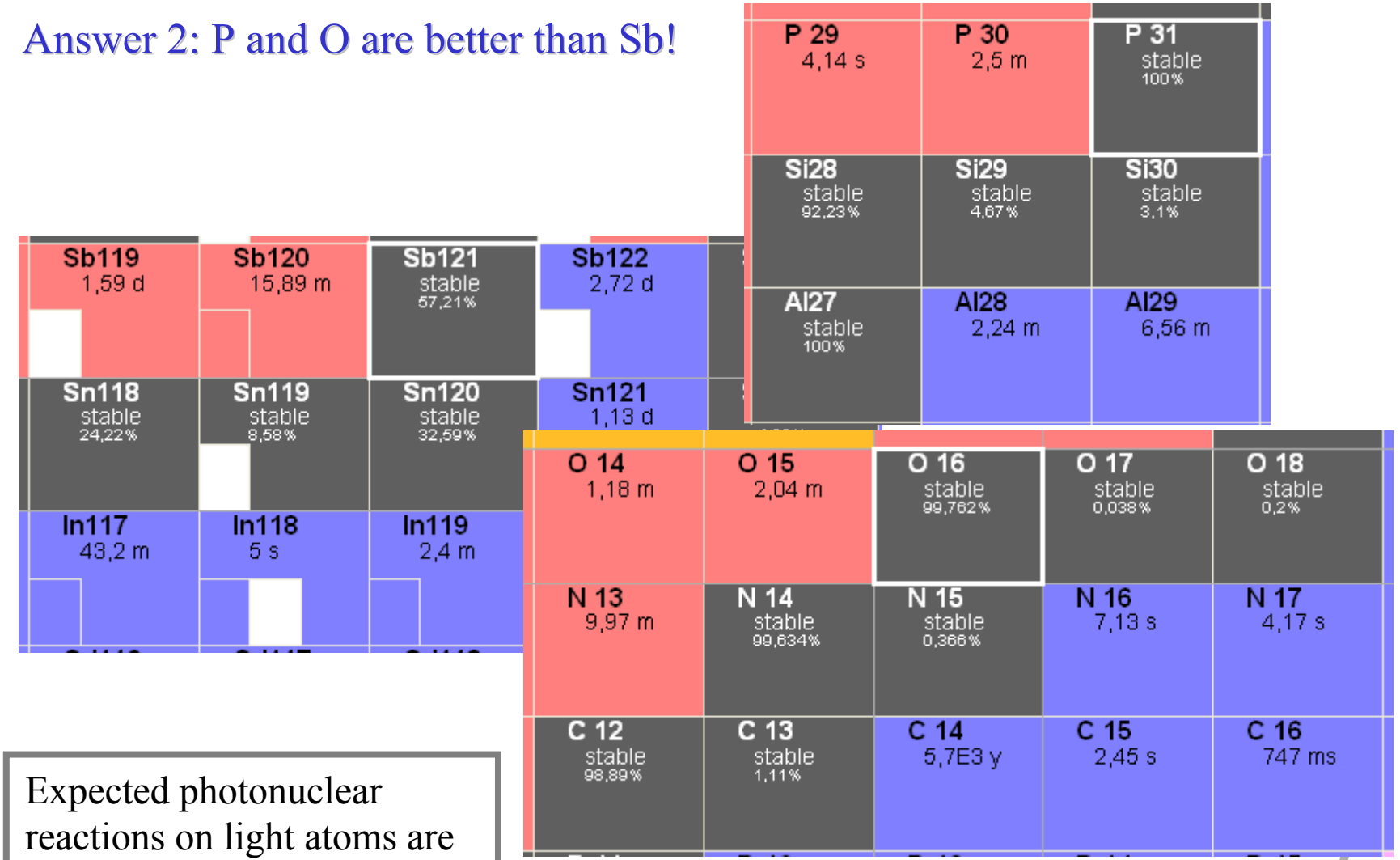
Photonuclear reactions on Plutonium #2

- We can select between different Plutonium forms
  - PuSb, PuP or PuO_2
- Which matrix is better to use?
  - We would like to reduce the γ background after irradiation

Find the matrix which has photonuclear reaction products with short half-life and/or no gamma lines.

Exercise 2: Which form is better: PuSb, PuO_2 or PuP?

Answer 2: P and O are better than Sb!

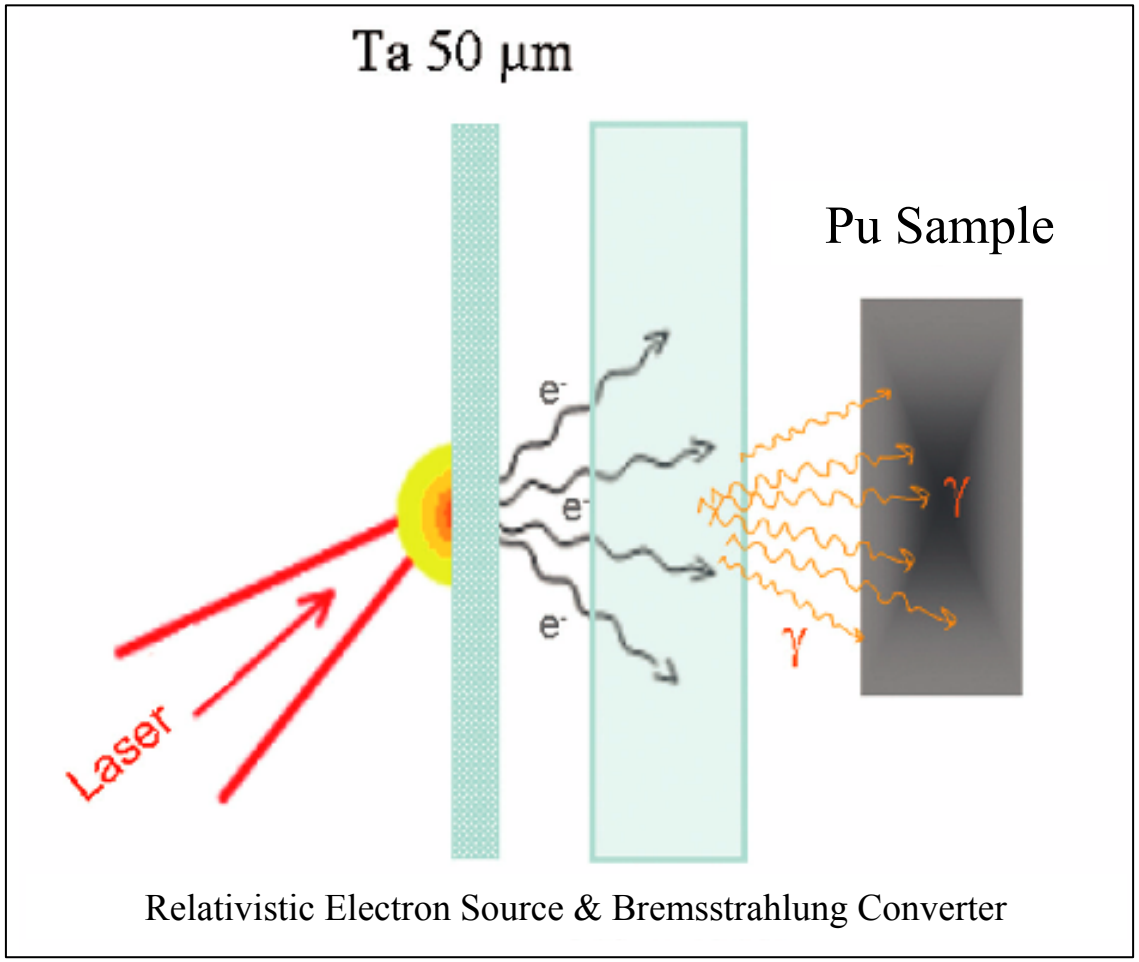


Expected photonuclear reactions on light atoms are (γ,n), (γ,2n), (γ,np), (γ,α)

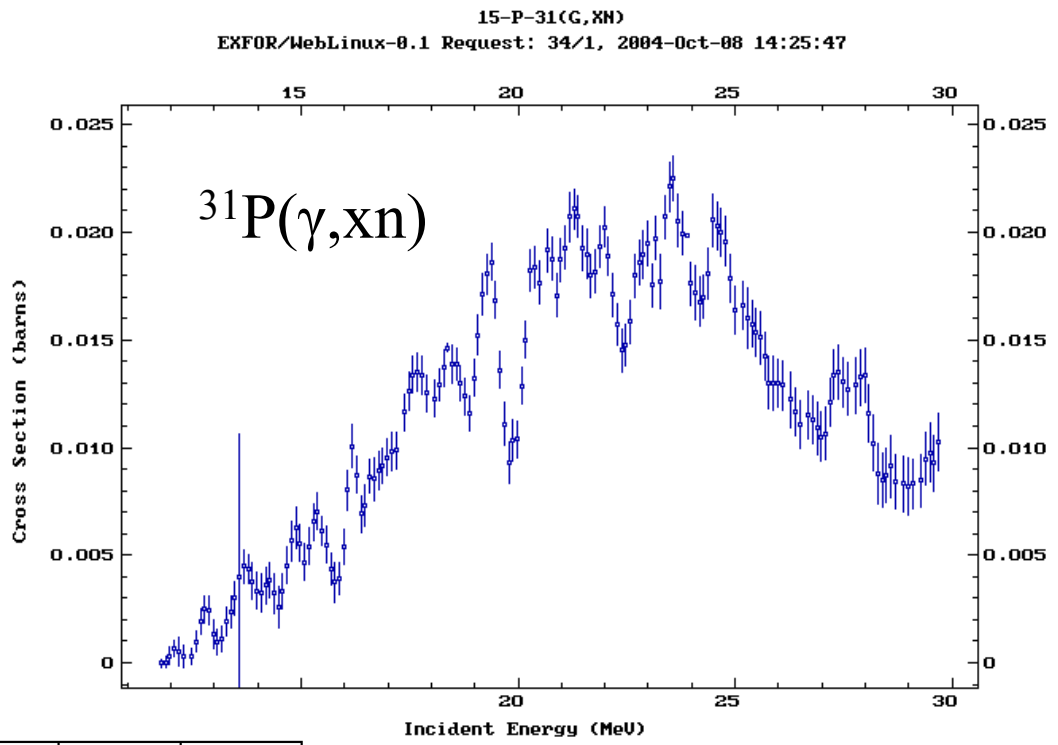
Conclusions

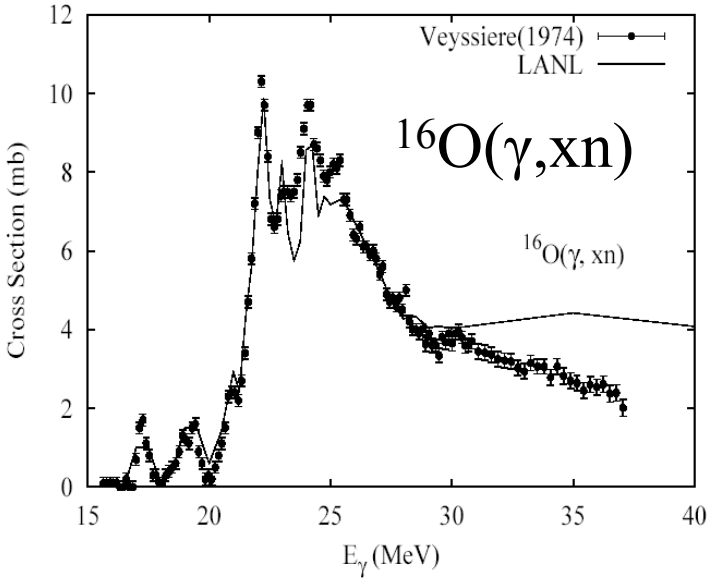
- In this feasibility study of photonuclear reactions on plutonium:
  - We have used the Nuclides.net to get an overview over different nuclear reactions and reaction products
  - We have used DataSheets and searched for additional nuclear data on the web through the Weblinks of the Nuclides.net
  - We have used Virtual Nuclides module and Decay module of the Nuclides.net to study the sample properties

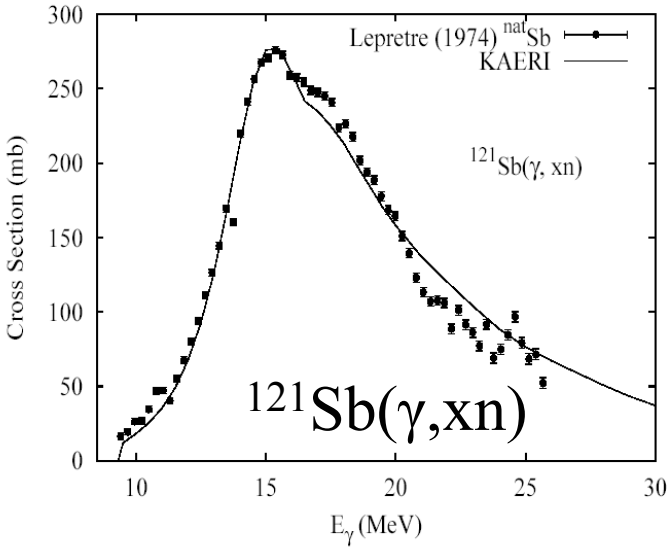
Thank You For Your Attention!



Relativistic Electron Source & Bremsstrahlung Converter







Data source: EXFOR